The characteristics of the cosmetic soils used by Bearded Vultures *Gypaetus barbatus*

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Bearded Vultures have a strikingly rufous colour to their head, neck and underparts, the intensity of which varies between individuals and localities. At one time these colour variations were used to establish new species (*G. albicans* Fatio, 1899) or subspecies (Fischer 1963). However, Berthold (1967) and Brown (1988) have shown that this colouration is caused entirely by the birds collecting iron-rich particles onto their feathers. The Bearded Vulture is the only bird species which is known to use cosmetic colouration from soils to such a spectacular effect. Clancey (1968), however, found it "*almost impossible to accept*" that such intense colouration was caused by iron staining, partly because no observations had ever been made of Bearded Vultures wallowing in red soils. His skepticism is understandable, for Brown (1988, 1990) during hundreds of hours of observations of Bearded Vultures during a three-year study in southern Africa never saw the birds using soil to stain the plumage. He considered that the birds may accumulate the colour incidentally, perhaps from filmy accumulations of iron oxide on rock ledges.

As a part of the programme to reintroduce the Bearded Vulture to the European Alps, a captive breeding programme has been established in Vienna and elsewhere, using birds from zoological gardens throughout Europe. Birds in captivity, if not given access to red soils, will develop pure white plumage. The captive birds have to be provided with red soils to develop their natural colouration. Captive birds only become excited when presented with certain intensely red-coloured soils, which are damp, but not liquid mud. They enthusiastically rub the belly and head feathers in the damp soil, and within an hour accumulate the characteristic deep, rufous colouration of wild birds. Once the feathers are stained in this way the colour cannot be washed out of the feathers by washing in water, although some soil is removed and the colour becomes fainter. The present paper considers the geological characteristics of the red soils which Bearded Vultures use for staining their feathers. We consider whether the distribution of suitable iron-rich soils may be limiting to the birds, or restricted in their locations, which might explain why birds have not been seen colouring their feathers in the wild.

Methods

Samples of soils were collected from a dolomitic limestone quarry beside the village of Groben, near Salzburg. They were subjected to X-ray diffraction analysis. The soils were first examined under a binocular microscope and the larger fragments were removed by hand, washed and mechanically ground in acetone to provide a glass-mounted

smear for X-ray diffraction using Fe-filtered Co Kα radiation at scanning speed 2° 2θ/minute and range 4 to 64° 2θ. The remaining material was smear mounted for analysis. Finally the clay particles from the soil were obtained using a sedimentation method and allowing one-hour settling time before recovering by centrifugation, the fraction containing particles of less than 10 micron. The clay X-ray diffraction profile was obtained using 1° 2θ/minute and range 4 to 16° 2θ for a sample presented untreated, glycolated, heated for 1 hour at 300°C and 1 hour at 600°C. The clay material was subjected to X-ray micro-analysis on a Cambridge Instruments scanning electron microscope for identification of major elements of the atomic number of sodium or above.

Results

The coarse soil particles were mainly dolomite and calcite, as were the main soil particles, excluding the coarsest grains. The finest clay particles were made up mainly of 14 Å clay (chlorite) and 10-12Å clay (mixed-layer illite/smectite) with possibly some 7Å clay (kaolin). The chemical analysis of the fine clay particles gave Silicon 17 %, Aluminium 11.5%, Iron 10.5%, Calcium 8%, Potassium 2.5%, Magnesium 1.5%, Sodium 1%, Phosphorus 1% and Titanium 0.5%. The glycolation and heating at 300°C provided clear evidence of an expanding component in the 10-12 Å clay, hence this is interpreted as a mixed-layer illite/smectite clay. There was only a trace of goethite and possibly a trace of hematite in the clay fraction.

Discussion

The soils used by the birds were gravels derived from weathered dolomitic limestone, a rock which is not uncommon in the Alps region. The quarry near Groben has rocks of a rich orange-red colour, and these coloured dolomites occur in several other localities in the Alps, but sometimes only in very restricted areas. The soil is mud which is washed out of weathered rock fissures by rain, and there are only a few sites in the Alps where these iron-rich muds are known to occur, and they are the only red soils known in the region. It is thus very likely that suitable cosmetic sites are very restricted for Bearded Vultures. The mineral dolomite usually contains iron in its structure and has a general formula $Ca(Mg,Fe)(CO_3)_2$. The iron oxidises readily on weathering to produce brown ferric oxides/hydroxides. The red colour of the soil is due to these iron compounds. Hematite (Fe_2O_3) and goethite FeO(OH) were both detected in trace amounts, but these minerals are often poorly crystallised and in partially hydrated states, so that their X-ray diffraction pattern is poorly developed, and they were probably more abundant than the results suggest; this is likely because of the high iron content from the chemical analysis. The main clay is a clay chlorite, but the illite/smectite which is also present would create a fine, absorbent material that has good adhesive properties for binding onto the feathers. Brown (1988) carried out electron microscope studies

of the feathers which showed that the soils often formed large 'blobs' on the ends of the barbs, and some barbules were so thickly coated that they were bonded together in clumps. He found that the soil was particularly accumulated at the ends of the barbules were the keratin had become frayed. A clay component to the soil, as well as a high iron content, therefore seems necessary. Hence the soil material seems to be ideal as a cosmetic. It combines a high iron content, providing a rich red colour, with a fine clay to give excellent bonding properties onto the feather, so that the feather retains much of the colour even after rain or bathing.

Brown (1988) noted that in the wild the colour of birds was correlated with recent weather; after periods of heavy rain the birds were noticeably lighter, and after dry periods were darker in colour. This colour change may be caused by leaching, as Brown (1988) suggests, but could also be caused by changes in the frequency with which birds visit sites with cosmetic soils, because captive birds have been observed mainly to use the damp soils during dry weather.

Despite detailed and close observations of the twenty released Bearded Vultures in the Alps over seven years, no bird has ever been seen using these red soils in the wild. The birds are provided with soil from the Groben quarry at their release sites. But it is known that some birds have found natural sources of mud—it is not known where—from which they have returned with their feathers thickly coated. Captive birds are extremely wary when using the soil, and will stop immediately there is any disturbance. From the lack of field observations anywhere in the world it is likely that birds in the wild are also very secretive about their visits to mud wallows.

Bearded Vultures are widely distributed over a great range of mountains of different geological origins. The populations in the Himalayas, Pyrenees and the Alps are all in limestone regions, where the soil type described here could develop wherever dolomitic limestone is eroding and weathering. The populations in Africa, which belong to a separate subspecies *G. b. meridionalis*, occupy the mountain areas of Ethiopia, East Africa and Lesotho and southern Africa. These mountains are composed of much older, metamorphic rocks. The characteristics of the soils used by birds in these areas must be different from the soil type described here, but African soils are characterised by high iron oxide contents, and sources of suitable cosmetic soils may be far more abundant. Brown (1988) carried out X-ray diffraction analysis of feathers and soil washed from feathers taken from birds in Lesotho. The material was found to be poorly crystalline, amorphous to X-rays, and probably a hydrous oxide of iron.

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IN BRIEF

MAGGOTS IN THE DIET OF THE COLLARED DOVE

Columbids in general are granivorous. Small snails are, however, regularly eaten during the breeding season as a source of calcium (e.g. Murton *et al.* 1964; *Ibis* 106: 174–188), and several genera, including *Streptopelia*, have been recorded eating other invertebrates (Goodwin 1970, *Pigeons and Doves of the World*). I report here the consumption of maggots by Collared Doves *Streptopelia decaocto.*

While studying the ecology of the Collared Dove near Ludhiana, I collected 206 birds for analysis of their gut contents, 10–20 in each month. None of the birds collected in 11 months of the year contained any insects. In July, however, 2 out of 16 (collected on 19 and 31 July 1985) had their crops full of maggots which were visible through the transparent skin of the crop. In one of them about 25% of the maggots were alive, and started moving about as soon as the crop was opened; they were alive probably because the bird was dissected immediately after being shot during the doves' peak feeding period (07.00–09.00 hrs). In the gizzards of both birds there were semi-digested maggots, their bodies hollow with the cuticle intact. Other food items present in small amounts in the guts of these doves were maize (1.09% by weight), wheat (0.29%), weed seeds (0.72%) and grit (5.80%); maggots formed the remaining 92.1%. Both birds were adult males in normal healthy condition, with no wounds or infections which might have accounted for the maggots. Collared Doves were often seen probing organic manure added to the fields, and also cattle dung kept in manure pits, and it is probable that the maggots were obtained in this way. In other doves whose gut contents were analysed, grain recovered from the crops sometimes had bits of dung attached.

The food of Collared Doves in this area (Saini & Toor 1994, in *Granivorous Birds in Polluted Environments*; PWN, Warsaw) is composed of seeds of cultivated and wild plants (85%) and grit (15%). Animal matter, especially snail shells, forms only <1% of total food. The recorded unusual intake of animal matter in the diet in July coincides with the period of food scarcity for doves. In my study area, there are two main crop seasons, viz. *rabi* (November–December to March–April) and *kharif* (June–July to October–November). Major *kharif* crops (rice, maize and pulses) are sown by the end of June and after sprouting become unavailable to doves. Saini & Toor (*loc. cit.*) reported that weed seeds formed the main part (53%) of the diet of